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ABSTRACT

To provide an overview of the possible impact of teaching machines on military training, several strategies were pursued: (1) several teaching machines were described; (2) the techniques of Pressey, Skinner, Crowder, and Pask were examined; (3) relevant research projects were reviewed; (4) appropriate military uses were suggested; and (5) methods for assuring proper use of teaching machine technology in military training were discussed. (EMH)

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TEACHING MACHINES IN THE MODERN MILITARY ORGANIZATION

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FOREWORD

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ABSTRACT

The concept of "teaching machines" is explained and its relation to military training problems is made clear. Descriptions are given of the machines and techniques of Pressey, Skinner, Crowder, and Pask. Some emerging theoretical issues are briefly presented and discussed. Research intended to develop the potentialities of the "teaching machine" concept is described by reference to the current research program of the Behavioral Sciences Laboratory. The military uses of teaching machines and of the efforts needed to make their widespread use a reality are discussed.

PUBLICATION REVIEW

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TEACHING MACHINES IN THE MODERN MILITARY ORGANIZATION

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I. INTRODUCTION

Teaching machines have aroused a great deal of interest recently in various professional and scientific fields. Appropriately enough the military psychologist has been among the most interested in this new technology. Training has always been one of the factors of vital importance to efficient military operations and in recent years has definitely become big business within the military. Within the U.S. Air Force, for example, it is conservatively estimated that over one billion dollars was spent on training operations during the past year. Consequently, military psychologists have devoted considerable effort to developing techniques, methods and devices for improving the efficiency of training. It is small wonder, therefore, that the teaching machine or automated training device has attracted the attention of the military psychologist early in its developmental history and has set his imagination racing. For these self-instructional devices hold out the promise of solving, or alleviating, a number of the problems that have beset military training.

Already three names have been used in this paper to refer to the topic under discussion—teaching machines, automated training devices, and self-instructional devices. These are the terms most commonly used, but there are others, and this diversity of nomenclature reflects both the newness of the field and the variety of special meanings which teaching machines have for different persons. Regardless of the terminology used, or the special interests of particular investigators, these devices constitute a class of instructional media with unique characteristics which differentiate them from other media. Throughout this paper, the three terms listed above will be used where each seems most appropriate.

Teaching Machines

Teaching machines are devices which provide effective instruction to a student or trainee without the direct participation of a human instructor. In other words, these devices simulate in one manner or another the functions normally fulfilled by a human instructor in individualized teaching or training. Their functions can be categorized generally as follows:

1. Presentation of information - Some machines present informational material by a display which is part of the device itself. Other machines depend upon supplementary sources of information such as textbooks or other adjunctive displays. In either type the information presented is the material to be learned and provides the background for the next function.

2. Presenting questions or problems - All self-instructional devices present the student with questions or problems to which he must make some active response. The questions or problems posed are keyed to the information which has been presented to the student for mastery. In some devices, functions 1 and 2 are combined. The information to be communicated is actually contained in the questions or problems which are presented. This purely Socractic method of instruction has been used with considerable ingenuity in some devices and more will be said about this technique in Section II.

3. Accepting and evaluating responses - As mentioned above, self-instructional devices require active responses on the part of the learner. In certain cases he selects his response from among alternatives which are presented to him, and in other cases he must construct his responses. All self-instructional devices also include some system for evaluating the student's responses against a criterion of adequacy.

4. Providing reinforcement - Closely associated with the function of evaluating the student's response is the function of informing the student of the adequacy of the response. This information, or knowledge of results, may be indicated by a "right" or "wrong" signal of some kind or may come from the student's own comparison of his constructed response with a standard. In any case, the prompt and clear presentation of knowledge of results is a consistent feature of self-instructional devices. In some cases a distinction has been made between knowledge of results and reinforcement, the argument being that confirming the correctness of a learner's responses to problems may be expected to be reinforcing only if the learner's motivation is intrinsic to the task being learned (ref. 4). Self-instructional devices are well suited to extrinsic reinforcement also, but this problem has not yet been carefully analyzed.

5. Programming learning - Self-instructional devices present material to the student in a manner and sequence intended to provide for efficient learning. The preparation and ordering of the blocks or "frames" of information to be presented by a teaching machine is called programming, and in all but the most complex devices, this function is performed by a human. Many self-instructional devices, however, are designed so that they can modify their program in a manner indicated to be desirable by the students' responses to questions or problems. Such a capability is called adaptive programming. The degree of adaptiveness among devices varies from merely dropping out mastered items in a serial program to selecting or generating problem situations which are highly tailored to individual needs.

Self-instructional devices derive their distinctiveness from performing all of the above functions in teaching or training a student. Other teaching aids, such as books, charts, films, and graphics, merely present information to the student, while more complex training devices, such as procedures trainers and simulators, require the constant presence of one or more instructors to fulfill the full range of teaching functions. The teaching machine alone provides true self-instruction on a routine basis by simulating the functions of the human instructor through electrical or mechanical means. As such, it provides a unique, new tool for exploitation in education and training.

Teaching Machines and Military Training Problems

Teaching machines have a special attractiveness to the military psychologist because they seem so particularly adapted to certain challenging problems in military

training. These problems and the relationship of self-instructional devices to them are discussed briefly below since the value of these new devices will have to be assessed in the setting of these practical circumstances.

1. Cost of training

Military training is expensive. It is costly first of all because of the complexity and diversity of the jobs involved and because of the large numbers of trainees involved. In fiscal year 1958, for example, the Air Training Command of the United States Air Force (USAF) gave technical training to approximately 300,000 men in several thousand different formal and special courses at a total operating cost of over $800,000,000. Since the major Air Commands also do considerable training, these figures represent only a part of the training within the Air Force. But training is expensive for another reason. It is expensive because there is so little time over which to amortize the cost of training. A large number of personnel given initial specialized training by the military services are available for only a single enlistment (as short as three years in the USAF), and even those who remain in the service require frequent retraining due to the constant introduction of new weapon systems. For these reasons, the ratio of training cost to useful work time is high in military organizations. There are several ways of reducing this ratio but one of the most direct is to reduce the cost of training. As a consequence, the military is always in search of ways to increase the rapidity and economy of training. Self-instructional devices offer a number of interesting possibilities here which can be appreciated without elaboration; need for fewer instructors, use of standardized materials, better and more flexible use of available training time, and assurance that efficient training techniques are being used.

2. Individual differences

Individual differences in ability to profit from instruction have always been a perplexing problem in education by anything other than a tutorial system. In military training, there is a problem of almost equal magnitude in spite of selection standards and aptitude testing. This problem, although by no means unique to the military, is accentuated by the requirement for extremely rapid training of large numbers of trainees. Self-instructional devices seem ideally suited to help alleviate this problem. These devices offer many of the advantages of individual tutoring without the attendant disadvantages of high cost, shortage of skilled instructors, etc. Automatic tutoring provides instruction paced to the needs of the individual student and can be adjusted to the trainee as he is at the specific moment. In this manner, each student moves through the instructional program as rapidly as his talents allow him.

3. Quality control

Military training requires rigid quality control of the products of training. Normally, the only purpose of military training is to develop specific human performance required in various military jobs. The specific performance must be produced with high reliability if a military operational capability is to be assured. Once again, the characteristics of teaching machines give cause for optimism with regard to this problem. Because teaching machines constantly measure and evaluate the trainee's performance in using what he has been taught, the teaching machine assures the proper level of all skills and knowledges that are required. Since training ceases only when each trainee has successfully dealt with each block of instructional information, a uniform and highly predictable product (i.e., trained man) is produced. Hence, for operational planning, much greater reliance may be placed on obtaining personnel with the required performance capability.

4. Shortage of instructors

The shortage of competent, experienced instructors is one of the most serious problems in military training. The etiology of this problem is complex, involving administrative factors and military tradition, as well as aptitudes of available personnel. Nonetheless, the problem exists and is a serious source of difficulty in most attempts to increase the effectiveness of military training. The self-instructional device is a natural solution to this problem and hardly requires elaboration. The use of automated training devices reduces the need for human instructors considerably. Because instructional material is centrally prepared, requirements for competence in those "instructors" which are needed in the field is also reduced. Therefore, such instructors as may be necessary will function more as proctors and will themselves need less aptitude and less formal training. Thus, a major barrier to improved military training is eliminated through the use of automated training devices.

5. Trainee motivation

Motivation is frequently a special problem in the military training situation. This is particularly true where the trainee is merely fulfilling an obligation for military service and has no career intentions with respect to military service. These people, moreover, usually constitute a significant proportion of the manpower available, and it is incumbent upon the military to use them as efficiently as possible. In the absence of career motivation, special attention must be given to making training an interesting and rewarding experience. Although there is not much firm data regarding the motivational characteristics of teaching machines, experience to date indicates that they are well received by trainees and that this positive reaction persists over substantial periods of time. More attention will be given to this problem in Sections III and V.

These are by no means all of the military training problems to which machines are germane. Nevertheless, the discussion should be adequate to explain the interest and enthusiasm of military psychologists for this new technology.

Scope of this Paper

So far, our discussion of automated training has been intentionally at a very general level. In the remainder of the paper, however, various aspects of this topic will be discussed with somewhat greater specificity. First, some representative automated training devices and materials will be described and briefly discussed. Next, some current problems and areas of investigation will be summarized and special attention will be given to some projects which have special relevance to the military uses of teaching machines. Lastly, some discussion will be devoted to possible uses of automated training devices in the military and to certain requirements which need to be met before these devices can be fully and effectively exploited.

II. SOME REPRESENTATIVE TEACHING MACHINES

A few years ago it would have been possible to describe virtually the entire population of teaching machines in the space we are now devoting to a "representative" sample. In fact, the proliferation of machines during the past two to three years has been so great that the "representativeness" of our sample probably is somewhat dubious. However, the machines selected for discussion do represent some of the major attempts to mechanize the instructional process.

Teaching Machine Design Depends on Programming Philosophy

In general, the term "teaching machine" is a misnomer. Most machines do not teach, they merely provide vehicles for the presentation of preprogrammed materials in a fashion which simulates some of the functions of an individual tutor. Thus, the characteristics of specific machines depend not only on the nature of the skills or knowledges to be learned, but also upon the particular programming philosophy to be implemented.

At the present time, there appear to be three major approaches to the programming of verbal and symbolic materials. The first of these is the simple multiple-choice approach originated by Pressey (refs. 13, 14). This is simply a variant of the usual objective examination augmented by self-scoring features, which provide the student with immediate feedback concerning the correctness of his responses. Pressey did not intend that his self-instructional tests and associated machines replace textbooks and other information presenting aids. Rather, they are designed to complement the conventional techniques by identifying areas of weakness and guiding the student in remedial study and review. Pressey's major contribution to teaching machine technology is his early recognition of the value of mechanizing some aspects of the training process.

The second major approach to programming is that developed by Skinner (ref. 17) and based in part, at least, on principles derived from his conditioning work with animals. His teaching machine presents the material to be learned in a fixed sequence and requires that the student's responses be constructed rather than selected from a multiple choice item. Another relevant feature is the "informational distance" between successive steps in the program is so small that correct responding throughout acquisition is virtually assured. In addition to Skinner's contributions to the art of programming, he is largely responsible for the recent surge of interest in machine instruction.

The third major approach to the programming problem is the variable sequence, multiple choice technique developed by Crowder, who labelled his approach "intrinsic programming" (ref. 6). His materials consist of units of information (usually a paragraph or less in length) followed by a multiple choice question related to the particular unit being presented. This approach differs from those involving fixed sequences in that student's response to a given question determines the material that he sees next. Thus, if he answers a question correctly he is presented the next unit in the main sequence. On the other hand, if he makes an error, he is shunted to a sub-sequence which permits him to review the previous material and explains the nature of his error. Thus, the amount of material to which a student is exposed is automatically tailored to his ability. This type of programming, like many others, does not require a machine for presentation. In fact, one of its most popular applications is a printed form called a "scrambled book." A scrambled book differs from the conventional book in that although the pages are numbered consecutively they are not read in the usual order. That is, after the student selects a particular multiple choice alternative he then turns to the page whose number is listed next to his choice. If he was correct, the material on the page confirms his previous response and presents the next unit of information. If he was incorrect, the information on the page is designed to clear up his misunderstanding before returning him to the previous page to try again. Crowder's machines, to be described later, provide more flexible semiautomatic mechanisms for storing and "turning the pages" of intrinsically programmed materials

To date, the major approach to the programming of machines for psychomotor skill teaching is that proposed by Pask (refs. 11, 12). Pask's approach is unique in that the teaching program is not completely predetermined. Rather, the machine is designed to emulate an ideal instructor who is in continual interaction with the trainee. It is assumed that the machine instructor and the trainee are engaged in a partly competitive, partly

cooperative game (ref. 12). At the outset of training the machine has very few built-in rules. The rules are developed during the course of play as the machine learns about the trainee and builds a model of his behavior which is used to adapt the training routine to his individual requirements. The basic control mechanism for accomplishing the tutorial functions in Pask's machines is a self-organizing computer which can be adapted to the teaching of a wide variety of job skills.

Pressey's Machines

Pressey is generally conceded to be the father of the teaching machine. In 1926, he described "a simple apparatus which automatically gives and scores a test, and which will also, automatically, teach—and teach informational and drill material more efficiently, in certain respects, than the human machine" (ref. 13). This early device, similar to that shown in figure 1, can be considered the prototype for the multiple

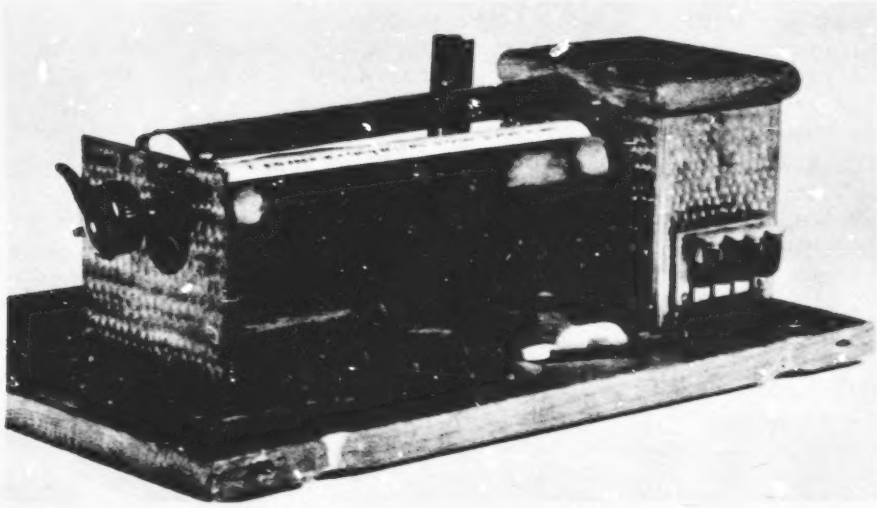

Figure 1. One of Pressey's Early Machines

choice approach to machine instruction. Basically, the device consists of a window in which multiple choice or true-false items are presented, a set of four numbered response keys which the student presses to indicate his answer, and a counter for tallying errors. The device has two modes of operation--a test mode and a learning mode. In the test mode the student is permitted to make only one response to any given item. After each response a new item is presented. In this mode no indication of response adequacy is provided. In the learning mode, on the other hand, an item remains in the display window until the correct button is pressed. Only then does the next item appear. Thus, in this mode the student is given knowledge of results after each response. This device also possesses the capability of dispensing a candy reward when certain goals are met. A later machine designed by Pressey (ref. 14) also incorporates a "drop out" feature. That is, the machine can be set to sequence through a given set of items one at a time until each item has been answered correctly on two, three, or four successive trials. As the selected criterion is achieved for an item, that particular item is "dropped out" on subsequent trials.

Skinner's Teaching Machine

Most of Skinner's machines require that the student compose or construct a response rather than merely select one (ref. 17). The simple disk machine in figure 2 is probably the best known of Skinner's devices. In this machine, material is printed

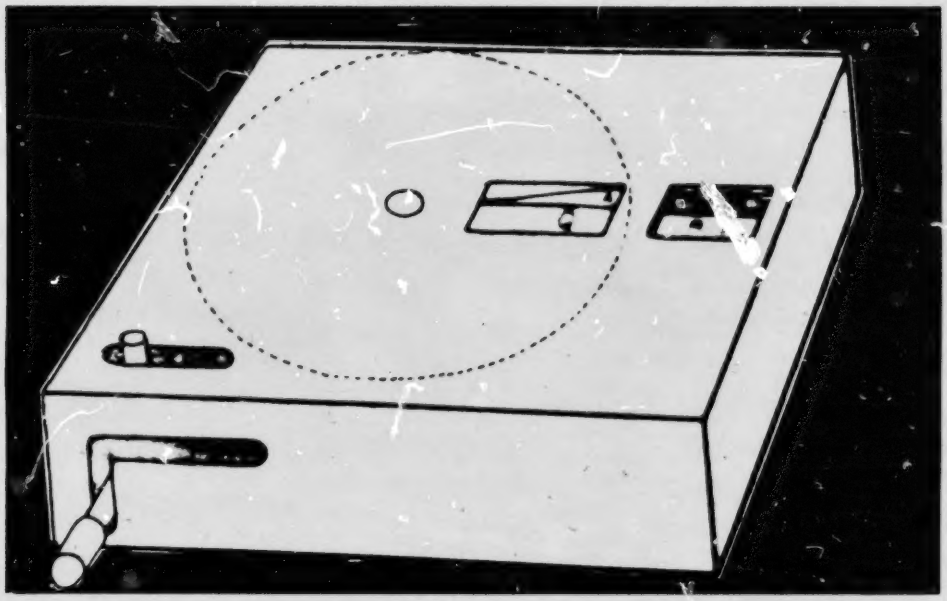

Figure 2. Skinner's Disk Machine

on 30 radial frames of a 12-inch disk. Each frame consists of a question or statement plus a correct answer. During the course of teaching, the statement only is exposed in the lower portion of a display window. The student responds by writing his answer on a paper strip beneath a second opening. He then operates a lever on the front of the machine which moves his response under a transparent shield and uncovers the correct response in the display window. If his response corresponds to the correct one he moves the lever horizontally. This punches a hole in the answer sheet opposite his response, recording his judgment of "correct," and modifies the machine so that this item will be skipped during subsequent presentations of the program. He then returns the lever to the starting position and a new frame is presented. The student continues to work through the program until all items have been answered correctly. When this occurs the disk revolves without stopping and the assignment is finished. Other constructed response devices have been designed in which the student composes his answer using a set of alphabetic and/or numeric sliders. The student's answer is compared by the machine with a coded response. If correct, the machine automatically presents the next frame. If incorrect, the student's response is cleared and he must compose another. The machine will not advance to a second frame until the first has been answered correctly. Not all of Skinner's devices require response construction, however. He has recently been experimenting with a series of preverbal multiple choice machines for use with young children (ref. 5).

Subject Matter Trainer

The Subject Matter Trainer was developed by the USAF to provide an automatic means for teaching and testing certain kinds of technical information without the aid of an instructor (ref. 1). This device has many features in common with Pressey's earlier machines. Each of 20 stimulus items is presented one at a time in a display window located on the left side of the panel, shown in Figure 3. The 20 response items

Figure 3. The Subject Matter Trainer

are mounted in a scrambled order on a plate at the right side of the panel. Coded answer plates are readily interchangeable to permit new orders for correct response items. Each response item is located between a response button and a green indicator light. The device has two digital counters for recording student performance. One counter advances one unit for each response made by the student while the other tallies only correct responses. A later model of the trainer also incorporates a "drop out" feature similar to that described for Pressey's machine above (ref. 2). The following six modes of practice are provided by the trainer:

1. Quiz mode

The name of this mode is somewhat misleading, since it is the machine and not the student that is being "quizzed." When a stimulus item appears in the window the student presses a "quiz" button which illuminates the green light next to the correct answer. Thus, the machine guides the student through the correct response sequence for the entire series of stimulus items.

2. Modified quiz mode

In this mode the "quiz" button is deactivated. When a stimulus item appears, the student is required to press the response button next to his chosen answer. If his selection is correct the green light next to his answer will glow, and the machine can be advanced to the next stimulus item. If he is incorrect, however, a red light glows and a buzzer sounds indicating an error. Simultaneously, the green light next to the correct answer comes on telling him what his answer should have been. The student then must depress the correct answer button before the machine can be advanced.

3. Practice mode

This mode is like the previous one except that the student must continue pressing buttons until the correct answer is found. When the correct answer finally is selected, the corresponding green light will glow and the machine can be advanced to the next stimulus item.

4. Single try mode

In this mode the student is permitted only one response for each stimulus item. After each response he receives either a red or green light.

5. Paced practice mode

This mode is primarily for experimental use. It permits duplication of the "practice" and "single try" modes by an experimenter who controls the rate of appearance of new items.

6. Test mode

In this mode the student receives no feedback concerning the adequacy of his response. He is permitted only one response to each stimulus item before being required to go on to the next stimulus item.

Crowder's Machines

Two versions of automatic, random access, microfilm projectors have been developed for use with Crowder's intrinsically programmed materials. An early

prototype was developed a number of years ago by the USAF. This first version was called the Multipurpose Instructional Problem Storage Device, or MIPS. Recently, a much improved device was designed and fabricated under Crowder's direction at the Western Design Division of U.S. Industries, Santa Barbara, California (ref. 7). This latest model, which is shown in Figure 4, is known as the Western Design Autotutor.

Figure 4. The Western Design "Autotutor"

The program in the Autotutor is stored on 35-mm film, and both still and motion picture material may be intermixed. The advertised storage capacity of the device is 10,000 35-mm frames, although with a thinner film base this may be increased to 30,000. In use, the student is presented with a unit of information on the viewing screen, along with a multiple choice question based on that unit. He then selects the next image to be presented by entering the number associated with the response he chooses into the selector buttons of the Autotutor. He next presses a "View" button, and the device automatically locates and projects the selected image. He then proceeds on through the program in the manner described previously. The machine can automatically record and print out on paper tape both the sequence of images viewed by the student and the time spent viewing each image, if such information is desired.

Pask's Machines

The most publicized of Pask's machines is the Solartron Automatic Keyboard Instructor or "SAKI" (ref. 12). This device was designed to teach the operation of a keypunch mechanism such as that used for punching IBM cards. As can be seen in Figure 5, the major components of the system are a display unit, a keyboard unit, and a small self-organizing computer which controls the training routine and records errors. The display unit consists of a back lighted stimulus card with four lines of exercise material and an analog keyboard. Initially, the item to be punched by the student is indicated by illuminating both the appropriate figure on the stimulus card and the corresponding key position on the analog keyboard. During the early stages of learning the rate of presentation of stimulus items is relatively slow. However, as the student gains proficiency with respect to speed and accuracy, the rate of presentation of stimulus items progressively increases to a preselected maximum and the illumination of the keys on the analog panel

Figure 5. The Solartron Automatic Keyboard Instructor (SAKI)

gradually decreases to zero. Throughout training, the computer continuously adapts the stimulus program to the unique characteristics of the individual trainee. Other versions of this device are being developed for use with adding machine and typewriter keyboards. In addition to keyboard training, Pask has also investigated the use of a self-organizing computer in conjunction with a complex radar simulator for teaching pilots the tactical and maneuvering skills required in airborne interceptions (ref. 11). In this application, the computer (EUCRATES Mk 1) served the function of a highly skilled instructor in adapting training exercises to the particular needs of individual trainees.

III. CURRENT PROBLEMS AND AREAS OF INVESTIGATION

On first impression it might seem that the diverse array of self-instructional schemes and devices would present diverse problems requiring an immense series of highly specific investigations. And, indeed, the first research on teaching machines was directed at some of the more specific and obvious issues. The initial research tended to investigate problems such as, whether to require a constructed response as suggested by Skinner (ref. 17), or whether to allow a choice among multiple response alternatives; whether to present but a single series of items to everyone, or whether to have branching programs such as those used by Crowder (ref. 6); whether to sequence the instructional items in such small "steps" that error responses would be virtually impossible, and so forth. Although some investigations of this type are necessary, a more systematic approach is desirable and seems to be emerging. Systematic programs of research should assure generalization of research findings to a wide variety of devices and materials to be learned, including both verbal and nonverbal tasks.

Approach to Teaching Machine Depends on General Systematic Viewpoint

To maintain proper perspective about teaching machines, two facts must be recognized. First, teaching machines have no special or unique status in psychology. They are merely a specific example of the dynamics of teaching. The second fact to remember is that various authors and investigators apply their diverse and previously formulated viewpoints or scientific approaches to considerations of teaching machines. Because different authors have different conceptualizations of the teaching process, and even different philosophies of science, their approaches to teaching machines and their research are different, not to mention differences in terminology. Awareness of the basis for certain apparent differences should provide some perspective by which to understand and interrelate diverse sources of information about teaching machines.

Skinner's (ref. 17) approach to teaching machines, and pertinent research influenced by his approach, quite naturally is consistent with his general approach to behavioral science. The research is pragmatic. Much of it consists of evaluating the effects of "programs" (sequences of instructional questions) prepared in accordance with a number of previously formulated principles. Sometimes the research implies as much about the ability of the investigator to practice the "art of programming" as it does about the principles of programming or any other conditions of the investigation.

A different approach to teaching machines is illustrated by Silberman and Coulson*. Although they have not so stated, their approach, which emphasizes the statistical interrelationships among items in a program, is related to mental test theory. Gagne and Bolles (ref. 9) imply a still different approach to automated training. They conclude that the same factors govern the efficiency of learning whether the learning is controlled by a machine or by any other means. However, they also point out that, compared to traditional research on the influence of specific variables on the learning process, research on teaching machines is characterized by a much more intense search for the conditions that maximize the efficiency of learning.

Pask (ref. 12) approaches teaching machines from the viewpoint of cybernetics and game theory. He conceives of the student and the instructor as two self-organizing systems engaged in a game which is partly competitive and partly cooperative. Pask, Carr (ref. 4), and probably many others, including the present authors, believe that both the use of and research upon teaching machines must be guided by a functional analysis of the interactions among the learner, the material to be learned, and any type of teaching guide or "instructor." The "instructor" may be solely human, both human and machine, or solely machine. However, even a common point-of-departure such as a functional analysis of the instructional process will not counteract the effects of different theoretical or systematic viewpoints. We may expect diverse programs of research on teaching machines for many years to come.

Research Program of Behavioral Sciences Laboratory

No attempt will be made in the present paper to present a comprehensive review of the current research on teaching machines. Such a review is a major topic by itself, and, since a significant portion of the research still is unpublished, the review would be very difficult to prepare at this time. To provide at least a sample of current research, a summary will be provided of the program of research on teaching machines that is being conducted by the Behavioral Sciences Laboratory.

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* Personal Communication

1. Development of automated instructional programs and facilities

Before meaningful and reliable research can be carried out efficiently it is necessary to have self-instructional materials that can serve as research vehicles, and facilities of sufficient flexibility to allow a wide range of experimental variations. To obtain the most valid and reliable information about automated teaching, it is necessary to conduct investigations in an actual instructional context and to measure the effects of a full course of instruction rather than just an hour or two of instruction. Development of these instructional vehicles constitutes one facet of the teaching machine program of the Behavioral Sciences Laboratory.

2. Effective displays of information in training systems

This research concerns problems such as the extent to which the symbolic form of the instructional information is a factor of significance. For example, under what circumstances is it best to use actual objects, pictures of them, symbolic representations, or verbal descriptions? What is the maximum, or the optimum amount of information that a learning individual can handle effectively at an early stage of training, and at later stages? Is there a relationship between desirable redundancy and amount of information? What is the effect of competing, or distracting stimuli? Could their presence serve to render the learner less vulnerable to the inevitable processes of forgetting?

3. Effective ordering of information for automated training

Is there a hierarchal, or merely sequential order that is optimal for the learning of concepts and skills? It is often said that one must walk before one can learn to run. The implication is that one must have mastered certain sets of responses before one can successfully learn certain other sets of responses. To the extent that this is true, it will have an impact on the program for learning any knowledge or skill. Among the other problems in this area are the optimal sizes of incremental learning steps between items in a program, sub-sequences or branching sequences in programs, formation and employment of mediating concepts, effects of eliminating items that have been mastered, and so forth.

4. Assimilation of information during automated training

One of the most important characteristics of automated teaching or training is the opportunity to obtain an observation of the student's response at each step. The deviation of this response from the expected standard can be used as an error signal to guide the "instructor." A continual analysis of the discrepancy between the information that was presented to the student and the information in his response can be used to adjust and readjust the instructional presentation until all of the information is assimilated. Research will be concerned chiefly with (a) rapidly detecting assimilation of instructional information, and (b) relating performance measures to display and programming variables.

5. Motivational aspects of automated training

Automating instruction requires a faith that the trainee will be motivated to engage in the instruction. Experience in a limited range of situations seems to offer some basis for this faith; however, in military situations, experience may be less favorable. Often the military trainee neither desires instruction, nor cares about the consequences of failure to master his lessons. Research will be required to design teaching machines that maximize the trainee's willingness to interact with the device. Instruction imbued with intrinsic value will be especially necessary when teaching are used to reclaim time that otherwise would be wasted.

6. Applications of automated training

Not only is it necessary to field test available forms of automated training to establish their practicality, cost, flexibility, etc., but also it is desirable to learn something about particularly favorable applications. For example, is self-instruction best used with groups of relatively high intelligence, or with groups of relatively low intelligence? In what sort of duty environments can it be successfully employed? How can it best be used at isolated sites? Can it be used even when the instructional content tends to change rather frequently as, for example, in the case of a new weapon that is still undergoing frequent modifications?

The program that has been sketched is being implemented with a number of research investigations. Only a few of the major ones will be mentioned. First, there is the development and evaluation of a prototype automated technical training course. The objective of this large scale field test is to make use of one form of automated training that is within the present state of the art and to demonstrate with it the practicality of automated training in a regular technical school context. This project is being carried out in cooperation with the Air Training Command of the USAF. The "test vehicle" is the Electronics Fundamentals Course taught at the Keesler Technical Training Center, Keesler Air Force Base. Data are being collected which will permit the comparative assessment of conventional and automated course administration relative to products (i.e., trained people), time requirements, costs, and administrative difficulty. In addition, the data obtained will have implications for the actual need for expensive devices and principles of programming employed. The method of "intrinsic programming" associated with Crowder (ref. 6) will be used in this field evaluation of an automated technical training course.

In cooperation with the University of Pittsburgh, we are developing self-instructional programs for studying principles for programming printed materials. The initial phase of this project will be devoted primarily to the development of printed (or microfilmed) programs that can serve as stable vehicles for future research. Several subjects will be chosen and examined from the point of view of implicit teaching objectives and hypothetical classes of principles applying to their programming. Then a final selection of a minimum of two subjects will be made and several program variants, each embodying specifiable differences in hypothetical programming principles, will be prepared for both of them. Simultaneously, a set of objective evaluation instruments (proficiency tests) will be prepared and standardized. When both types of materials are ready, they will be used in a preliminary experimental study of program variations. Concurrently with all of these activities an attempt will be made to arrive at a preliminary specification of the major (hypothetical) principles and procedures of programming printed materials and to collect them in a Procedures Handbook suitable for use by training personnel.

Another research effort is being carried on by arrangement with System Research, Ltd., in London, England, through the European Office of the USAF Air Research and Development Command. This effort will be concerned with the development of a logico-mathematical model of a system which not only adapts itself in several ways to the student's study behavior (e.g., frequency of presentation of an item, rate of presentation, etc), but moreover senses the success of its own tactics and shifts them when necessary. Thus, if the system detects that its present mode of operation is not leading to the most efficient mastery of the learning task by the student, it will either eliminate some of its presentation tactics, or continually change the weight that is given to them. Once the feasibility of such a system has been determined the model will be given some kind of concrete form. At the present time it is not yet known whether it will be a digital computer program, involve some kind of an analog device, or perhaps consist of nothing more than a "game" to be played by several learners.

Another area of active effort has to do with the study of motivational issues in automated training. Enthusiasts of automated training almost without exception take for granted the willingness of the trainee to expose himself to self-instruction. Although novelty effects may attract and hold the military trainee for a while, novelty alone can not hold him indefinitely. It has been proposed that the instruction provide "intrinsic" motivation if it is to maximize the trainee's desire for the instruction. However, no clear concept of intrinsic motivation or how to achieve it is available. Our initial efforts in this area have been devoted to a systematic analysis of the meaning of intrinsic motivation and an attempt to state a rigorous, operational definition. Appropriate experimental investigations are now being planned. Several minor investigations have been conducted on problems such as prompting the responses of the learners, the rate at which new material is presented to the trainee, and the pace at which the program items are presented.

Current research, we hope, will some day provide us with automated training techniques of much increased efficiency and with new applications that have been either not considered hitherto, or have not been feasible. While effective techniques are being improved or created, the existing techniques may be used with profit in many training situations. Even at the present time, it is clear that substantial benefits can be obtained from automated training techniques in a variety of military applications.

IV. SOME MILITARY USES OF AUTOMATED TRAINING DEVICES

So far in this paper we have commented on the general relationship of automated training to military psychology, described some representative devices and discussed some current research issues and projects. Undoubtedly this material has already suggested to you numerous possibilities for applying automated training devices in the field of military training. On first impression, it would appear that there is no problem at all in thinking up all sorts of uses for these devices. Indeed, whenever an instructor is involved in a program of training, we have a potential for automating the functions of this instructor. But perhaps we are moving too fast; potential does not necessarily mean pay-off. Contrary to much popular thinking, it is not always technically desirable to substitute machines for men. Rather, the assignment of functions to man and machines in a system should be based upon a careful analysis of the capabilities and limitations of each in relation to the functions that are required to produce the desired system output and, this is true regardless of whether the desired system output is lead pencils, bombs on target, or trained personnel. As Bryan and Rigney (ref. 3) so nicely put it in their discussion of automated tutoring, " 'The machines will save us' fallacy is so firmly rooted in current thinking that it may not be recognized in this new guise."

In other words, any discussion of the uses of automated training devices in military training (or any other training or educational program, for that matter) which attempts to become specific, must immediately come to grips with the following two problems: (1) defining the role of the instructor in training programs of various types and (2) assessing the comparative abilities of human instructors and machines in fulfilling these roles. These problems have not yet been carefully analyzed and studied. However, McKeachie (ref. 10) has pointed out that teaching machines have focused the interest of teachers and research workers alike on these problems, and that the results of such interest may well improve human as well as automated instruction. Indeed, he feels that this may be one of the major benefits to be derived from the current interest in automated tutoring.

When A Machine can Profitably Fulfill Instructor Function

Rather than attempt a detailed analysis of the functions of the instructor, and then compare the ability of men and machines to fulfill these functions, we will discuss the military uses of automated training devices in certain extreme classes of instructional situations. Our discussion will be limited to cases where the instructor functions undoubtedly could be assigned with profit to a machine because the functions are too routine, the functions are too complex, or no human instructor is available.

1. Use of A Machine when Instructor Functions are too Routine

In the first case, we are dealing with situations where it is advantageous to use automated training devices because the instructional situation is highly standard and routine. It will be apparent immediately that these are the same conditions under which it usually is profitable to introduce automation in industrial manufacturing operations. A little reflection will suffice to determine that a substantial amount of military training meets these criteria. Facts, nomenclature, and procedures must be memorized. Concepts and principles must be mastered. Data flow and component locations and interrelationships must be understood. A significant proportion of the time required for training in a military specialty usually is devoted to developing an understanding of a technical area, to serve as a basis for later skilled performance. In such cases the materials to be mastered are specifiable in advance and the criterion of mastery is unambiguous. The instructional task is that of presenting the material in a manner that will insure efficient mastery. Traditionally, this is done by having students sit in classrooms and listen to carefully outlined and frequently memorized lectures, study textbooks and manuals, participate in occasional recitations and drills, and infrequently take examinations. Delivering "canned" lectures, listening to recitations and drills and grading objective tests is a patently inefficient use of human instructors. In the first place, instructor personnel can be used more efficiently for work which cannot be done by machines and which requires more of their unique capabilities (e.g., determining what information the student needs to be taught and programming this material for effective learning). In the second place, inexpensive, automated devices can be designed which can probably out-do the human instructor in accomplishing the routine teaching functions mentioned above. Normal classroom instruction is heavily dependent upon passive listening and provides little opportunity for active response on the part of the student. It provides meager feedback to the student concerning his progress and relatively little chance for adjusting the pace to each individual's capabilities. The teaching machine, on the other hand, presents material in small amounts, provides for active response by quizzing often, delivers continuous feedback and adapts the instructional pace to the individual student. In short, the teaching machine seems almost ideally suited to this routine type of instruction. There will be problems in their use, of course, such as educating training personnel in their proper utilization, preparing subject-matter programs for the machines and integrating them into the existing training framework and concepts. Nevertheless, it can be said with some confidence that the effort will be well repaid in improved training and more effective use of available instructional personnel.

2. Use of Machine when Instructor Functions are too Complex

Sometimes, we are dealing with situations where the instructional task is quite the opposite from that discussed above; situations where the instructional task is too complex or too difficult for effective accomplishment by human instructors. Here again we have a counterpart in the industrial situation, where many complex data processing operations are handled by computers with a great consequent increase in efficiency. If it can be truly said that much military training involves the routine acquisition of

knowledge and concepts, it is just as true that much military training involves the mastery of highly complex, extremely sophisticated skills both on the part of individuals and teams. Humans must be trained to monitor and control highly complicated machinery such as supersonic aircraft and aerospace systems. People must be trained to assimilate large amounts of information from diverse sources and make rapid decisions, as in missile count-downs. Teams of individuals must be trained to perform in an integrated manner in large data processing systems such as the USAF SAGE system. The skills involved in such operations are difficult to master and typically require long periods of intensive training involving much practice in realistic job environments. Historically, such practice was acquired in the job environment itself with an instructor present both for tutorial and safety purposes. Recent military systems, however, have been far too demanding on human skill to permit this approach completely; therefore, complex, ground simulators have come into vogue to aid in providing both transition and maintenance-of-proficiency training. As weapon systems have increased in complexity, so too have the training simulators, and these modern devices now have complex instructor-operator stations and require teams of instructors and trainer operators in order to provide realistic training sessions. Even so, the requirements for coordinating, controlling and scheduling rapidly changing inputs, monitoring the complex response outputs of students, and providing for realistic interaction between the two are rapidly outstripping the capabilities of human instructors. Likewise, the requirements for rapid recording and analysis of complex, multivariate events is increasing, and it is upon this function that providing knowledge of results to the trainees and programming future instructional exercises is dependent. All of these facts point to the conclusion that there is a class of military training problems where the role of the instructor must be taken over to some degree by automatic equipment. Here, of course, we are dealing with quite a different type of automated training device from the relatively simple, inexpensive teaching machines used in presenting classroom instruction, but the concepts and rationale are the same. We are discussing an automated or self-instructional simulator. In such a simulator, the machine, in addition to its usual role of providing system simulation, takes on the functions of automatically recording and evaluating trainee performance and of adaptively programming subsequent events to maximize the trainees approach to criterion performance. Computers, with their capacity for short term storage of huge amounts of information, rapid search and rapid computation are well suited to perform these functions which humans perform quite poorly. With machines performing these functions, high quality instructional personnel can be used entirely for tasks such as determining what aspects of human performance to record, formulating criteria of performance adequacy for various stages of training, and developing programs of problems for the simulator. These are things which the machine cannot do. Thus, we have both men and machines doing those things which they do best and, once again, improved training should be the result. Automated simulators as operational training tools are still somewhat in the future and considerable development work remains to be done, but the Eucrates device described in Section II has proved that the concept is definitely feasible and necessity should soon force the issue.

3. Use of Machine when no Human Instructor is Available

In some situations automated training devices are desirable for the simple reason that no human instructional personnel are available. In such cases, if instruction is to be carried on at all, some type of self-instruction is required. There are a number of military situations where this is true. Some examples are remote or isolated early warning radar or missile launch sites, aboard naval vessels and, in the near future, aboard orbital or space vehicles. In all of these examples, of course, the type of training required is not initial training but maintenance of proficiency training. Individuals assigned to these military situations presumably would have been well trained in formal training courses prior to their assignment, but provision must be

made for maintaining their proficiency on the job. This problem of maintaining proficiency will become more and more critical in the military as the expense and complexity of weapon systems increases, thereby reducing the opportunity for day-to-day practice of critical job skills. It seems obvious that missiles cannot be fired often for training purposes nor space vehicles launched to provide an opportunity for the crew to practice some particularly difficult portion of the mission.

Maintenance of proficiency training in military settings which are cut off from access to formal instructional facilities poses special problems, and it is in this area where automated training devices should prove very useful. Books and manuals have been used effectively for many years but they generally are of limited value in training for jobs which demand rapid decision making and/or perceptual-motor skills. In these areas, some type of automated training device would seem indicated. Types of devices which would prove useful pretty well cover the gamut of those discussed thus far and no further descriptions of devices will be made here. Rather, two brief examples of situations requiring automated training devices will be presented.

(a) Isolated Radar Sites:

Remote, isolated early-warning radar sites involve a great deal of complex electronic equipment which must be maintained by the small complement of personnel stationed at the site. Since continuous operation of the radar screen is vital, prompt identification, isolation and repair of malfunctions is a necessity. To accomplish this, the ability of maintenance personnel to troubleshoot all types of possible malfunctions must be maintained at a high level. On-the-job experience cannot be relied upon to accomplish this, since the actual occurrence of malfunctions is fortuitous. What is needed are devices which can automatically present the maintenance man with a wide range of troubleshooting problems, assess his proficiency, and concentrate subsequent training in areas of weakness. Only in this way can the continued proficiency of the maintenance man in all aspects of his job be assured throughout his tour of duty.

(b) Space Vehicles:

Long duration missions, such as those involving interplanetary travel or extended orbital flight, could present some serious problems with respect to the maintenance of little used, but critical behaviors (ref. 8). For instance, according to present calculations, it would be several months from launch until a manually controlled soft landing on Mars could be effected. In the interim, there would be no opportunity for on-the-job practice. Thus, this extremely critical maneuver would have to be performed without even the benefit of warm-up. In the absence of firm research data to indicate that this particular skill is sufficiently resistent to forgetting, it would seem highly desirable to provide an on-board capability for maintenance of proficiency training. The same argument, of course, could be made for in-flight maintenance tasks on long duration space missions.

These are just a few examples of where automated training technology can be used with profit in current and future military operations. They indicate, however, the wide range of possibilities available and will perhaps serve to stimulate other ideas in this area.

V. MILITARY EFFORTS NEEDED

As we have seen in the previous section there is no dearth of possible uses for automated training devices in military training. But listing possible applications for some new advance in the state-of-the-art is quite a different problem from assuring implementation. The history of military psychology, at least in the United States, is rife with examples of failure to achieve rapid and effective utilization of new techniques, methods, and devices. Although some of the blame for this may be attributed properly to the strength of tradition in the military, some must also be laid at the door of the military psychologist. We have perhaps not always been the best salesmen. It is entirely appropriate, therefore, that before concluding this paper we consider the problem of what needs to be done by military psychologists to justify the current enthusiasm for teaching machines and to insure their effective exploitation by the military.

Efforts Needed to Assure Proper Use of Teaching Machines

Currently there are three areas in which military psychologists need to program their efforts to increase the probability that the potential of teaching machines will be recognized and used in military operations. These three areas are discussed briefly below:

1. Demonstrations of effectiveness

Demonstrations of the effectiveness of automated trainers in realistic military training situations are needed to obtain required military support and to justify further interest in this field. Too often we have failed to realize the value of demonstrations in military psychology and have neglected this important step. In our enthusiasm to put our ideas to work, we have often put them forward before testing the concept. This is not necessarily bad if the ideas have a great deal of logical validity, but the chances of getting our ideas accepted are reduced if their feasibility has not been demonstrated. In our eagerness to begin programmatic research on a concept or idea, we often have asked for support without giving hard-headed evidence of why such support is justified. We argue, with some validity, that research is required to identify major variables, their effects and their interactions before demonstrations can be accomplished. But, often valid demonstrations are possible long before completion of all of the detailed experimentation required to optimize conditions. In the teaching machine area we should strive to avoid committing either the error of pushing utilization without caution or of exercising too much caution by hiding our candle under a bushel of long-term research programs.

Such attempts to demonstrate effectiveness are not without hazard, of course. There is always the chance of failure due to a poor choice of conditions, and it would indeed be unfortunate if the real potential of automated training were beclouded by an early failure. As Bryan and Rigney (ref. 3) have pointed out, there is also a danger that successful demonstrations will force a premature crystallization of teaching machine concepts and procedures. This would be quite unfortunate and certainly must be resisted. Nevertheless, the potential gains seem greater than the pitfalls and efforts to demonstrate the effectiveness of teaching machines in military training situations certainly should be supported. As was mentioned in Section III some attempts are currently being made to accomplish this and these efforts are a good start toward putting the program on a firm foundation.

2. Imaginative planning for use

Assuming successful demonstrations of effectiveness, the military psychologist then is faced with the task of assisting, and in many cases leading, in planning for the use of automated training devices both in existing training programs and in programs which are being developed to support new weapon systems. This will require imaginative and careful planning. No one or two successful demonstration studies will indicate where and when to push for the introduction of automated training devices. Yet, if history is any guide, the danger is that we will not use all that we know; rather than that we will go further than our knowledge permits. Therefore, it seems appropriate to recommend that military psychologists use all means at their disposal to assure that automated training technology is applied in all areas of military training where it appears to offer significant advantages over current practices. This will require salesmanship as well as science, but military psychologists must learn to mix these liberally to be effective.

3. Systematic applied research program

We have a significant amount of information about teaching machines at the present time and can recommend their use with considerable confidence in a number of military situations. Nevertheless, if these devices are to be fully exploited, one of our primary needs is for an aggressive, systematic applied research program to further advance our knowledge in this area. If present trends continue, there seems little doubt that this need will be fulfilled without any special urging. Research in the area of teaching machines, after a number of rather lean years, is now increasing by leaps and bounds. Figure 6 below, which is reproduced from Bryan and Rigney (ref. 3), presents the trend over the past dozen years.

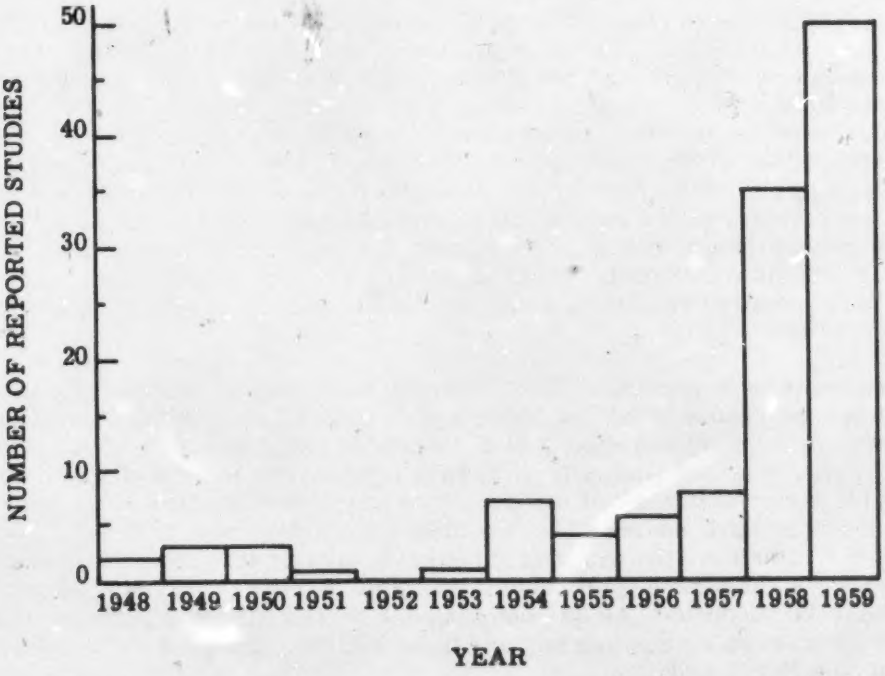

Figure 6. Frequency per year of Teaching-Machine Studies, From 1948 to September 1959. There were six references prior to 1948.

There seems little need in this paper, therefore, to make the usual plea for more research. Many competent investigators are busy identifying relevant problem areas and conducting programmatic research. We can expect with some confidence that much valuable information will be generated within the next few years.

It would be pleasant to end this discussion on such a reassuring note, but to do so would give the military psychologist a false sense of security. There are a number of problem areas which are closely related to the military uses of teaching machines which require study by the military psychologist before any large scale use of teaching machines can be recommended. Most of these problems are being neglected by current investigators. Some of them may not even qualify as research in the usual sense of the word, but their importance is not thereby decreased. Some of the more important of these problems are mentioned briefly below.

(a) Motivational aspects of automated training

Trainee motivation has been discussed earlier as one of the challenging problems in military training to which automated training devices might make a contribution. Yet, little is known at present about the long-term motivational properties of these devices, and an answer to this question is basic to their large-scale use. Great teachers have long been known for their ability to motivate and inspire their students and there probably will be no such great teachers among the teaching machines. On the other hand, there probably will not be any really bad ones either. Teaching machines can be designed so as to present instructional materials in an efficient way. What we need now are some studies as to how they can be designed so that the student's response to them will be positive both initially and on a continuing basis.

(b) Support requirements of automated training

The types of facilities, services, and personnel support required to operate conventional training programs have been well worked out through the years. One of the biggest dangers in the immediate, large-scale use of teaching machines is that users will expect that no changes in supporting facilities and services are necessary or, still worse, that these devices can be expected to function relatively autonomously in the training environment. Although we know that this is not true, we are not yet able to specify clearly and with confidence the nature and amount of support that will be required. High priority should be given to studies which will assess the impact of automated devices on current training concepts and programs.

(c) Integration with other types of instruction

It is inconceivable that automated training techniques will ever completely replace other forms of instruction. Rather, they will serve as supplements, in some cases rather substantial supplements, to so-called conventional methods. Considerable research will have to be accomplished before we can specify the ultimate role of these devices in training, but much can and should be done at the present time to assure their efficient and proper integration into current and planned training programs.

(d) Costing analysis

Machines cost money; sometimes substantial amounts of money. They also require maintenance; sometimes substantial amounts of maintenance. All this adds up to a definite price tag, including both direct and indirect costs, attached to any automated training program. People cost money, also, even though their cost is not always as obvious as with machines. Any decisions to substitute machines for people in a system will have to be based not only upon the relative capabilities of the two to accomplish the

functions assigned but also upon the comparative costs involved. This will be especially true in the area of training where the military is quite cost conscious. Therefore, military psychologists will do well in their studies, if they not only gather data on training effectiveness but also make provisions for a thorough cost analysis of the technique being studied. Such cost figures undoubtedly will be required before the military will make any large-scale use of automated training techniques.

(e) Improved specification of training goals

A clear specification of the goals of the training is a requirement for developing any program of training or education; it is by no means unique to a program involving teaching machines. With teaching machines, however, this issue is brought into clear focus because materials must be prepared down to the finest detail, tried out, revised and standardized before training begins. With teaching machines there is no such thing as going to class unprepared and "bluffing your way through." Nor is there much chance for hiding one's uncertainity about training objectives in wordy, highly generalized lectures. Rather, the exact material to be presented and mastered must be selected and programmed in advance. This means that the teaching machine programmer must come to grips with the goals of his training program early and without equivocation. The success with which this can be done is one factor which will determine both the effectiveness of teaching machines and their acceptance by training personnel. Therefore, a very important research requirement for the military psychologist is that of developing new and improved techniques for the detailed specification of training goals and standards before training begins, rather than by an after-the-fact analysis of the graduates of training programs. Such developments will have wide applicability to the field of training in general, but they are especially vital for the effective use of automated training in the military.

It is clear that there is no reason for the military psychologist with an interest in automated training to be idle in the next few years. There is much to be done, the time is ripe and the potential payoff is high.

VI. CONCLUDING REMARKS

No one can say for sure at present what the future holds for teaching machines. Several highly ingenious and imaginative accounts of teaching machines' possibilities have been put forward, e.g., Ramo (refs. 15, 16). We certainly do not deny a bright future for these devices, but we believe that any such bright future is best assured by a well conceived, step-by-step building of the present. About the only prediction we can make with confidence is that the next few years in this field will be active ones.

There is a great deal of current activity and study in the area of teaching machines; these devices appear to have considerable potential for the field of military training, but there still is much work to be done before this potential can be fully realized. Actually, today the practical use of self-instructional devices and materials is merely in its infancy, but perhaps no single idea in military psychology since the selection test has created such interest and has had such far reaching implications for improving military operations. This is truly not only a great opportunity for military psychology but also a great challenge and a great responsibility. There is the opportunity to develop a tool which will bring considerable attention and great credit to our profession; there is the challenge of a psychological problem with depth and meaning; there is the responsibility to perform a significant service for the military organizations of which we are a part and from which we derive our support. It will be important for military psychology to meet this opportunity, challenge and responsibility with enthusiasm and maturity.

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